

Described is a management game that is programmed for use on a computer. The game provides participants the opportunity to make decisions regarding production, marketing, finance, and planning in a competitive industry. This game, implemented in APL utilizes interactive computing, giving participants more flexibility in the use of one of the most recent techniques in management gaming.

A general management business simulation in APL

by P. N. Wahi

Management games have gained wide acceptance in business and education during the past fifteen years. The first such game was developed by the American Management Association in 1956. Since then, management games of various kinds and levels of sophistication have been developed all over the world. Growth in the number of games and participants (users) has been tremendous because the power of simulation as a method of education has been increased many fold via the medium of computer technology.

The primary use of management games is to help the participants, be they executives in industry or students in business schools, to develop their ability to make difficult interdependent business decisions in real life, to evaluate new ideas, and to introduce new techniques of decision-making—all in a simulated environment. Furthermore, playing these games can be an enjoyable experience, and at the same time, it can offer a high degree of personal involvement and competitive spirit. The results gained, of course, are in direct proportion to the skills and resources expended in developing the game.

The use of management games in the business world is in some sense equivalent to the use of laboratory experiments in the physical sciences. The results of good or bad decisions can be examined quickly and without fear of real loss. Simulations of

business environments provide valuable experience in conceptualizing ideas and in logical thinking. Further, games can be used as a means of introducing management science techniques (statistical and mathematical) to give the participants training in model building and analysis. A sophisticated (not necessarily complex) management game can also serve as a stepping stone for development of information processing systems and corporate models.

In industry, management games are used in internal training and executive development programs; in universities, they are used in many business school curriculums as a teaching device. These games can be structured to be useful as a research tool to investigate the behavior of business organizations as social and economic entities. For a survey on management games, see Cohen and Rhenman.¹

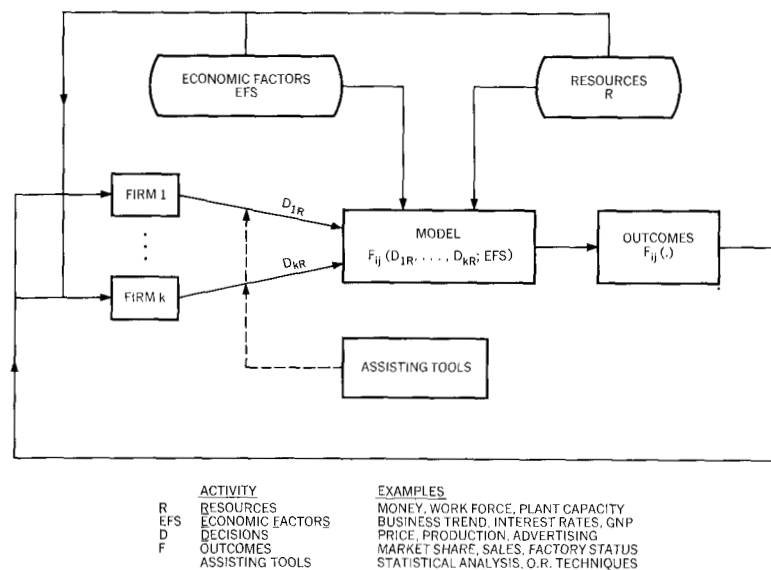
With the advent of interactive computing, the use of management games as a teaching, training, or research device is even more realizable. The aid of management science or operations research techniques in the decision-making process is enhanced because of the ability of the users to utilize the techniques interactively on various sample data in a single session via remote terminals. Data retrieval and manipulation are simplified to a great extent. This motivation has led to the development of an interactive management game called the Applied Information and Management System that forms the subject of the rest of the paper. The game simulates a hypothetical business environment of a manufacturing industry, and as such, the rules and relationships applied in the model are not necessarily representative of any real business.

This information and management system is a general computer management game involving decision-making in the functional areas of production, marketing, finance, and planning. The game provides an opportunity for the participants to make general management decisions in a competitive industry and serves as a testing ground for new ideas without fear of real loss. It emphasizes the importance of:

- The interdependencies among various decisions under uncertainty, giving rise to adaptive decision-making
- The need for planning to achieve the best allocation of resources and favorable outcomes
- The role played by management science techniques as aids in solving decision problems

The game is based on the original work of Levitan and Shubik²⁻⁴ and FAME,⁵ a game that has been used in IBM for almost a decade. The simulation is programmed in APL (A Programming

Figure 1 Schematic of a simulation model



Language), which provides an interactive conversational mode with unique capabilities in numeric and nonnumeric processing, in desk calculator mode, and in easy handling of arrays of data. Thus the participant is given a degree of flexibility not available in similar games. The whole simulation exercise (including inputs and outputs) can be operated in a user interactive mode via remote terminals connected to the central computer.

Basic model

A general model of the simulation of an industry can be viewed as in Figure 1. An industry uses some basic resources and is influenced by the prevailing economic factors. There are k firms in the industry competing for a market share of some product(s), the outcome being influenced by exogenous factors (e.g., economy) and endogenous factors (e.g., price of products). The "assisting tools" box is optional but can help firms in analyzing the data and arriving at a better set of decisions.

The organization of the simulation is viewed in the following perspective. The game is played by a number of teams (representing firms in a manufacturing industry) that are competing for a market share of some product(s) in various market regions. The simulation is run for a series of decision periods with all input and output taking place at an APL terminal. At the beginning of each period, decisions are entered by all the firms before the simulation run is made that updates the data for each firm. Reports are generated to inform the teams of the outcomes

of their decisions. As in real life, a firm does not have access to most of the data of another firm. The firms study the outcomes, analyze the data, and get ready to input the decisions for the following period.

In a normal setting, the following parameters are typical in the simulation exercise:

Number of teams (firms)	3-4
Number of persons in each firm	4-6
Number of products	2 (arbitrarily named A & B)
Number of market regions	3-4
Plant operation	2 shifts with/without overtime
Decision period	1 quarter (3 months)

All of the above parameters and many others that are required as initial conditions of the simulation exercise can be easily changed or reset because of the modular nature of the program. Some key parameters can be set at values that may emphasize particular aspects of the industry environment, e.g., pure price monopoly, violent competition, no price interaction, cooperative advertising, etc.

For the sake of convenience in our discussion, the management game that we are describing can be grouped into three major phases that are repeated every decision period:

1. Input
2. Simulation run
3. Output

Each of the three phases will now be described in some detail. Although the description pertains to the Applied Information and Management System program, the general principles and ideas needed to develop other scenarios in other environments should become evident to the reader. The description also illustrates the scope of use to which the game can be put.

**input
for
model**

The first phase of any simulation is the identification and description of the input: variable input and parametric input. The parametric input (even though variable in a sense) sets the initial boundary conditions for the simulation and is not ordinarily changed throughout running of the simulation exercise. Examples of parametric input in our game are: the number of teams in the game, the number of products, the number of market regions, and the production costs. Within the set initial boundary conditions, the variable input can be changed to make several simulation runs. The variable input in the game is the set of deci-

sions that various firms (teams) make each period; each period constitutes a simulation run. The decisions on the following factors are under the control of each firm and can be entered via a remote terminal.

Price: Price of each product offered for sale has to be specified in all the market regions. In general, the higher the price, the lower the demand.

Production: Production volumes during regular and overtime shifts are to be specified for each product. Production costs are linear but vary in different shifts. Actual production quantities may have to be modified in the simulation because of a lack of facilities to produce them. The reduction is a proportional one. Also, only half of the quantity produced is available for sale during the period.

Distribution: The quantities to be shipped to various market regions are specified for each product. There is a linear shipping charge for each product to each market region. Because of the varying distances of warehouses from the firms' plants, the shipping cost is different for each firm, product, and market region. Again, the quantities shipped might be modified in the simulation if inventory levels cannot meet the shipping schedule. The reduction is a proportional one.

Advertising and Promotion: Advertising for each product and local sales promotion in each market region are permitted. Competitive and cooperative effects of advertising are controlled by parameters in the simulation. The impact of advertising and promotion is cumulatively lagged over several periods.

Labor: Hiring or laying off of labor can occur at the beginning of each period. There are costs incurred in both hiring and laying off a worker. A natural fixed attrition rate is assumed in the absence of laying off or laying off below the attrition rate. A new worker hired is only partly productive in the period hired and fully productive afterwards; therefore, new hires are assigned to the first shift during the first period of employment and are not assigned for overtime work until fully productive. Overtime is restricted to half of assigned regular shift time. The unassigned labor force (because of not enough of a production level, or raw material, or plant capacity) is paid first shift rates during the period. Fixed administrative expenditures to operate various shifts and produce various products are taken care of as parameters in the simulation.

Plant Capacity: Plant capacity is expressed as a number of identical machines. A firm may choose to increase its plant capacity at the beginning of each period at a fixed price per machine.

There is a two-period lag between the decision to increase plant capacity and the installation of that capacity. New machines have to be ordered to maintain or increase plant capacity, and depreciation of the value and capacity of equipment is linear. The depreciation is charged for the first shift hours only, regardless of the usage of machines. A fixed maintenance charge is also incurred on each machine for each period.

Raw Materials: Only one surrogate raw material is assumed. All of the raw material on hand is available for use, but there is a lead time required for the delivery of new raw material if ordered at the beginning of the decision period. All raw material ordered is delivered by the end of the period, but only a proportion of it can be used for production during that period. The cost of raw material is a fixed amount per unit.

Research and Development: Such expenditures improve the marketability of products and influence the sales over a number of decision periods in some proportionate manner. New research and development expenditures must be incurred, like advertising and promotion, to maintain its effect on demand of the products.

Government Securities: At the beginning of a period, a firm may invest in 90-day government securities that mature at the start of the following period. The securities are paid for immediately and earn interest at a specified rate which is received as cash at the start of the period following that in which the securities mature. They can be short-sold at a loss to meet the firm's financial obligations to avoid bankruptcy.

Debentures: Debentures provide a means of raising cash for the firm. The value of the debentures requested may not exceed a certain percentage of the net worth of the firm at the time of issue. An interest rate must be paid to the holders of debentures. The debentures mature over a period and payments are made each decision period in equal installments. A firm may float a maximum of two debenture issues.

Dividends: A firm may declare dividends at the start of a period to be paid at the end of the period, provided all the debts and obligations are paid for without resorting to a bank loan. Dividends improve the image of the firm in terms of its stock value and also earn compound interest on the cumulative sums paid as dividends. However, there are limits up to which dividends can be paid by a firm.

Market Research: Market research is a device for additional data gathering to study the behavior of the market subject to changes in the strategic decision variables of (a) price and (b)

advertising and promotion policies. Every period a decision can be made to undertake market research activity at a fixed cost, or run one or more market surveys also at a fixed cost per survey.

Bank Loans: Bank loans are treated in a special manner. Each firm is required to have a specified minimum cash balance at the end of every period, and money is borrowed automatically from a bank to meet the financial obligations and minimum cash requirements subject to a limit on the line of credit. Loans are automatically repaid as soon as the firm has enough cash available in the following period(s). The rate of interest to be paid on outstanding loans in the following period is determined for each firm based on its financial standing (i.e., stock price) in the market during the period.

If a bank loan is insufficient to meet the financial obligations of the firm and the constraint on the minimum cash balance, then the firm may be declared bankrupt.

After all of the firms have entered their decisions, everything is ready for the next phase, viz., simulating the industry based on the decisions.

The simulation

The core of a simulation is the model that accepts the input, analyzes or processes it according to a set of rules or formulae, and generates the outcome of the analysis (processing of input). The model in this game consists of three modules, one for each of these areas: manufacturing, marketing, and financing. Each of the modules is briefly described below; discussion of most of the mathematical relationships is omitted for clarity in exposition.

Each firm possesses a plant, a work force, and raw materials which form the three basic factors of production. Each of the two products that a firm can manufacture requires a different combination of these factors. Availability of the three factors limits production. All reductions, if required, are proportional to the quantities ordered. Finished goods can be stored at the plant or shipped to the market region warehouses. In short, the manufacturing module accomplishes the following for each firm:

manufacturing module

- Determines actual production schedule subject to constraints of machines, work force, and raw materials
- Modifies shipping schedule if necessary
- Updates factory and warehouse inventories

Costs are incurred in manufacturing and shipping to warehouses as well as in storing products for inventory. Inventory costs are

charged on average inventory during the period. All costs are linear.

**marketing
module**

The market simulates the behavior of customers in response to price and product availabilities, their preferences being modified by advertising, sales promotion, and research and development activities of the firm. Conceptually, the market consists of two types of customers: the "loyal" customers, who do not switch brands unless price varies, and the "switchers," who can be lured away by advertising, sales promotion, and research and development activities of a firm.

A firm may not be able to supply all the demand in a market region if it is "out-of-stock." A percentage of the excess demand (the really loyal customers) may be back-ordered, and the rest is redistributed among the other firms, to the extent that they can supply the excess beyond their original market share. The rest of the unsupplied demand, if any, is assumed to be lost.

The effects of advertising, sales promotion, and research and development activities are cumulative and lagged over time. There are both competitive and cooperative aspects of these activities. For convenience they are referred to as "effective advertising and research." Product promotion and product development are necessary to stimulate the demand. The demand function for the i th firm is a generalization of the following basic equation:

$$F_i(p, a) = \frac{W}{n} \{ \beta - \alpha [p_i + \gamma(p_i - \bar{p})] \} f_i(\theta, a) \left\{ 1 + \eta \left[\sum a_i + (1 + \epsilon_i) \right]^2 \right\}^{\frac{1}{2}},$$

where

$$f_i(\theta, a) = \begin{cases} \theta + (1 - \theta) \frac{\eta a_i (1 + \epsilon_i)}{\sum a_i (1 + \epsilon_i)} & \text{if } \sum a_i > 0 \\ 1 & \text{if } \sum a_i = 0 \end{cases}$$

$$W = r^t [1 + \lambda \sin(\omega t + \nu) + \epsilon]$$

and all terms are nonnegative.

In the demand function, W represents the possible effect of business trend, cycle, and random variations coming from the economy. On the right side of the last displayed equation, r^t is the growth rate of the economy at time t , ω the angular velocity of the business cycle, ν the phase angle of the cycle, λ the amplitude of the cycle, and ϵ a random variable. In the basic equation, the second factor in the first set of braces deals with the effects of price, p_i , and price relationships in the market. The term γ is a param-

eter which reflects an inherent degree of substitutability between products, and α reflects the sensitivity of overall demand to change in price. An estimation of α can be made from the elasticity of demand. The parameter β controls the overall market size and is generally very large. The function $f_i(\theta, a)$ accounts for the competitive effects of product promotion and development, whereas the last factor in the second set of braces represents an overall institutional effect of "effective advertising and research," a_i , on industry demand. The term ϵ_i is a random effect component. The current average price of the product is $\bar{p}$, and n is the number of firms in competition.

Thus, the marketing module determines for each firm:

- market share for each product in each region
- actual sales versus demand
- back-orders, if any

New inventory levels in the regional warehouses are determined after sales have taken place.

The financial module captures the results of all the activities and actions undertaken during the period in terms of dollar value. Each period, the firms must make financial decisions relative to investment in government securities, payment of dividends, issuing of debentures, and purchase of new equipment. Other financial revenues and obligations arise as the result of activities in the production and marketing of a firm's products. Bank loans, which can cover the cash obligations of a firm to an extent, are automatically drawn as required and are to be paid back when possible. Inability to meet the financial obligations beyond the outstanding line of bank credit can result in bankruptcy of the firm.

financial
module

The cash transactions simulate the continuous flow of receipts and payments such that the income from operations offsets the expenses. Standard cost accounting is used for manufacturing operations and variances of cost are computed. The financial module thus takes care of the working relationship between incomes, expenses, and cash flows of each firm.

Output of a simulation serves as a way of relating the outcome of the simulated activity to the input provided for the simulation. In our management game, the output serves as a way to inform the firms (teams) of the outcome of their decisions and actual activities that took place during the simulation. This forms a basis of information to help make decisions for the following period(s). The output is generated in terms of reports that can be grouped in various ways depending on the information required and ease of interpretation. The seven standard reports are:

output

1. Profit and loss statement
2. Balance sheet
3. Cash flow statement
4. Finished goods and production report
5. Factory and warehouse status report
6. Marketing reports
7. Competitive performance reports

Besides the standard reports, other data, including historical information, are resident in the data base and can be accessed by the users. All the reports and data can be obtained on the remote terminal.

Decision-assisting tools

As an aid to effective decision-making, decision-assisting tools can be made available for use by the teams as part of the simulation exercise. These tools offer the opportunity to demonstrate the role of management science techniques in decision-making and to enable the participants to get some exposure to model building and analysis. With the game being discussed, four such tools are available—two provide assistance in planning and financial analysis, and two involve applications of linear programming and regression analysis. All are programmed in APL and are used in an interactive conversational mode.

Linear programming can be used to effectively procure and allocate resources of production during the simulation exercise. The linear programming model optimizes the production decisions subject to the constraints and the criterion of optimization.

Multiple regression techniques can be used to determine relationships between different variables in the market place. The results of the regression analysis of the latest available data can be used to forecast demands of products and to make pricing and product promotion decisions. Market research and surveys provide additional data for analysis.

System setup

APL⁶ provides an interactive conversational mode very suitable for remote terminal usage in a time-sharing environment. The present system uses APL under Disk Operating System/360 or Operating System/360. Various aspects of the game are programmed in separate modules such that changes in any can be made with minimum inconvenience. Most of the data are organized in the form of easily accessed matrices and arrays, providing a good basis for developing an information system.

A schematic of the operation is depicted in Figure 2. The sequence is as follows:

1. Firms load their respective work spaces, get reports and enter decisions
2. Instructor (Administrator) loads main work space and copies the decisions of all firms to enable simulation run
3. Historical data update, get reports
4. Go to step 1

The computer resources requirement in APL is given in terms of work spaces and their sizes. The number of work spaces required for the game is given by four plus the number of teams participating. Sizes of the work spaces vary, but the recommended size for operation is 77 K bytes. There is a trade-off between the number of work spaces and their sizes; increasing one reduces the other.

Running time of the simulation (excluding input and output) is approximately one minute for each period simulated on a System/360 Model 67.

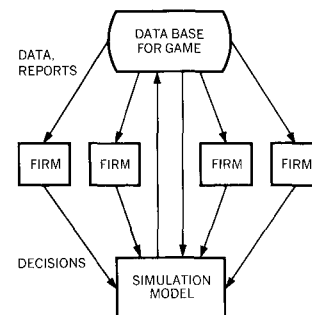
Summary comment

A general management game has been described that simulates a manufacturing industry environment and is programmed in an interactive conversational mode using APL. The game has proved to be a valuable means of training individuals in decision-making. Further details are given in Reference 7. The game is also used for experimental purposes, and improvements are being made constantly to reflect the results of research being carried out in the fields of gaming, simulation, and decision-making in an economic environment. To the author's knowledge, this is the first major application of APL in simulation and gaming.

Future plans are: (1) To develop the data base in some form by a mini-management information system easily accessible by the users and utilized in both query and problem-solving environments. The idea is to do away with standard reports and encourage the participants of the game to develop their own information systems. (2) To do further research to reflect the changing economic environment. At present, the influence of the economy is treated in rather a parametric manner. Also, the financial investment opportunities of the firms can be enlarged.

Future work of interest would be to use the game as a research tool and data-organizing system to analyze how people make decisions in an industrial environment and to study the effects of

Figure 2 APL system setup for game
— a cycle



interaction between the various aspects of decision-making. This particular type of game can be of use in investigations of the behavior of oligopolists and the structure of organizations. Future use of computers in education and research will be enhanced with such methods.

CITED REFERENCES

1. K. J. Cohen and E. Rhenman, "The role of management games in education and research," *TIMS* 7, No. 2 (January 1961).
2. R. Levitan and M. Shubik, *A Business Game for Teaching and Research Purposes, Part I*, Research Report RC-730, IBM Thomas J. Watson Research Center, Yorktown Heights, New York (July 17, 1962).
3. R. Levitan and M. Shubik, *A Business Game for Teaching and Research Purposes, Part IIA: Theory and Mathematical Structure of the Game*, Research Report RC-731, IBM Thomas J. Watson Research Center, Yorktown Heights, New York (July 17, 1962).
4. M. Shubik, *A Business Game for Teaching and Research, Part III: Discussion and Manual for Users*, Discussion Paper No. 180, Cowles Foundation, Yale University, New Haven, Connecticut (November 20, 1964).
5. *FAME: Financial, Allocation, and Marketing Exercise—A Business Simulation*, A report prepared by IBM at the Thomas J. Watson Research Center, Yorktown Heights, New York (April 12, 1968).
6. K. E. Iverson, *A Programming Language*, John Wiley & Sons, Inc., New York (1962).
7. P. N. Wahi, *AIMS—Applied Information and Management System—A General Management Business Simulation in APL*, Report No. G320-2066, IBM Cambridge Scientific Center, Cambridge, Massachusetts (April 1971).